Dental Unit Prototype With Electric Dental Chair and Dental Light Parameters

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ABSTRACT
In supporting dental examination and treatment tools, especially in regional health facilities, an economical dental unit that has already met dental examination standards is needed. In this study, the authors will design an electric dental chair using a pneumatic as an up and down drive and a linear actuator as a back drive for upright and lying down position using a remote control. As well as dental light as a light source for dental examination or care using the SHARP 2Y0A21 infrared sensor as a switch for four conditions, namely low, medium, high and off. The testing of dental chair was carried out by testing the function of the dental chair remote control for actuator and pneumatic, as well as giving a load to the chair, while for dental light testing, the value of light intensity was measured using a lux meter at a distance of 30 cm. The results of testing showed that remote can function as planned with an accuracy value of 100%, pneumatic can lift loads up to 120 kg with a load resistance error of 5 minutes at a height of 25 cm by 0.1% and at a height of 15 cm by 25%. In the actuator voltage testing, the average value of the voltage when it dropped was 11.80 VDC and when it rose was 11.20 VDC, the lowest error was 0.6% and the highest error was 3.5%. The light intensity testing obtained an average result at low condition of 2032 lux, in medium condition of 8435 lux, and in high condition of 20280. In testing, the SHARP 2Y0A21 sensor function worked well with an accuracy value of 100%. Based on the test results obtained, it can be concluded that this dental unit simulation can function like a dental unit in general with all parameters that can work according to its function.

Keywords: *Dental Unit, Dental Chair, Dental Light, Pneumatic, Linear Actuator.*

1. INTRODUCTION

Dental and oral health according to basic health research center Indonesia in 2018 recorded that the number of dental and oral problems had a percentage of 57.6% and only 10.2% received services from medical personnel [1]. This proves that public awareness about dental and oral health is still very low, the factor that affects this is because the facilities and services for medical personnel do not reach small communities such as at the sub-district level. Equitable distribution of dental health services at public health centers for middle to lower class people is still experiencing problems with lack of facilities. Many community health centers only provide dental units that are perfunctory or that are not functioning properly. The dental unit systems at community health centers generally do not meet the needs of doctors and patients. Community health center is a cheap and affordable dental examination clinic for the middle to lower class community, but that does not mean that the quality of service is ignored, many needs from patients and doctors have not been fulfilled by the existing dental units at the community health centers nowadays [2] .

Dental units are devices used for the examination and care of teeth and mouth (drilling, filling, cleaning and examination) [3]. Some parts of the dental unit are the dental chair, dental light, hand piece, micromotor and dental suction [4]. The dental chair functions as a place for patients to make it easier for doctors to perform dental examinations which have settings to change the level of inclination of the patient's legs and back, as well as the rise and fall of dental chairs, and dental chairs can move up and down and usually use motor and hydraulic actuators [5]. Dental light is a source of irradiation during dental examinations using a halogen or Light Emitting Diode (LED) type lamp so that there is no shadow during irradiation, the position or placement of the dental light can be adjusted as needed to make it easier for the doctor during the examination [6]. In addition, the prices of dental units on the market are expensive, so that health care facilities such as community health centers and clinics cannot afford this tool [7].

The previous research was conducted by [4] . In this research, the manufacture of a dental unit was in the form of a basic frame using existing frames and other materials in order to reduce costs. The results of this research showed that the design of the unit was attractive so that it did not give the impression of being scary, in addition the attractive design provided comfort for the user during the examination process, and was safe for use in all groups of pregnant women, children and adults. The advantage of this unit was the use of a dental unit design with a backrest material adapted from an office chair. In addition, dental chair machines used a motor actuator system at the height of the seat with hydraulic driving force as the main driving force for up and down and upright movements to reduce noise, as well as a dental unit design with anthropometry that fits all users. The disadvantage of this unit was that there was no dental light as irradiation during the examination, so the existing spittoon bowl (mouth rinse) could not be rotated, making it difficult for the user to move when rinsing. In addition, there was no storage area for the equipment used for water bottles on the side box. The cable channels on the handpieces tray were not neatly arranged which could hinder the operator's work.

The next research [8] was conducted which results showed that structures made of cast iron could function properly with technological equipment installed, meanwhile users could also monitor electronic equipment via web and store information about the unit, such as water pressure, air pressure, voltage and electric current. The advantages of the unit were that the seat position could be adjusted to the height and low using hydraulics, and there was a headrest that could be used to help the user when doing examination, the lamp used was not hot with a light intensity of 13,000 lux to 28,000 lux, and the dental suction used had suction power less than -80 mmHg and could operate in conjunction with a saliva ejector. The disadvantage of this unit was that it still used hydraulics as a driving force for the up and down of the chair, the use of hydraulics allowed for oil leaks and required routine maintenance, as well as dental lights that had not used sensors as switches so that the cleanliness and sterility of the user could not be achieved [9].

Afterwards, a research was conducted by [10].From the research conducted, it can be concluded that the design of a sheet metal cutting tool with a shering machine could work properly using forward (push) and reverse (pull) system, pneumatic had better results. At the reverse (pull), the amount of pressure generated was $264{,}232N$ while the forward (push) had the amount of pressure of $294{,}375N$. In this tool, the researchers used a solenoid (solenoid valve) which acted as an open and close control gate/valve of the compressed air which will enter the pneumatic controlled by an electronic component in the form of a relay as an on/off switch of selenoid valve, and was equipped with a flow control valve which served to limit the amount pressure that will go into the pneumatic. The weakness of the design of this tool was that the use of electronic components still used an analog logic gate system and was often over delay.

Meanwhile, another research [11] in which the results of this research resulted in an average value at low light intensity of 587.1 lux, at bright intensity of 747.25 lux, and at brighter intensity of 1324.1 lux. The sensor used in this research was the HC SR04 proximity sensor to make it easier for users not to adjust the intensity of the operating lamp, the selection of the HC SR04 sensor was to calculate the distance between the lamp and the object, not the intensity of the lamp, which system was controlled by the ATMega328 microcontroller. The disadvantage of this tool was that the number of errors in the reading was still quite large, so that when the distance of the object with the lamp was far away, the light response was quite slow or less responsive.

Based on these problems, in this research, the authors will make a prototype of Dental Unit in the form of an Electric Dental Chair and Dental Light which is more economical than any existing tools by using a pneumatic as a seat drive to go up and down with the advantage that it is easier to maintain and the price is not too expensive, and uses a linear actuator as a back drive for the chair's upright and reclined position, equipped with a remote as a chair control to make it easier for the user when operating the tool [12]. It also Equipped with a dental light that uses SHARP 2Y0A21 infrared sensor [13] which is used as a switch to switch the light mode from low, medium, high and off to reduce the doctor's touch with other objects or items so that cleanliness and sterility can be achieved.

2. RESEARCH METHOD

2.1. Tool Design

The design of the unit aims to estimate the shape and arrangement of the components of the tool. The shape of the unit design can be seen in Figure 1.

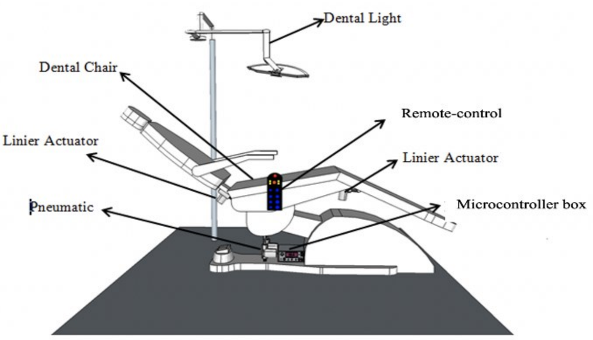

Figure 1. Tool Design

Tools and materials used:

- Dental Light in form of LED
- Dental Chair
- Pneumatic
- Linear Actuator
- Remote Control
- Microcontroller Box

2.2. Flowchart

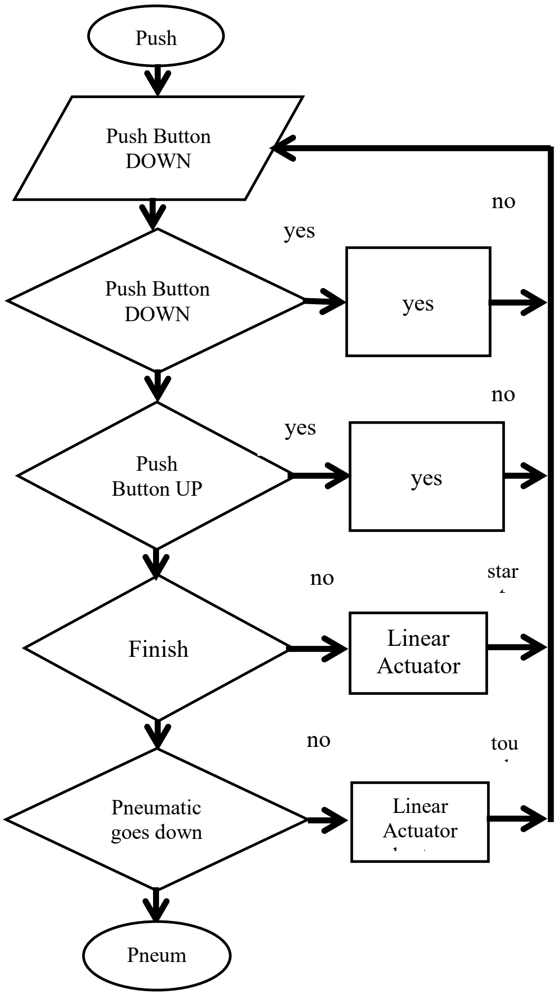

Figure 2. Dental Chair Flowchart

It can be seen from the Figure 2 that the process starts with the initialization of the push button reading or command, so when the push button is pressed to up, the installed pneumatic extends and the dental chair rises, when the chair push button is pressed to down, the pneumatic will shorten which causes the chair to drop, meanwhile when the back button is pressed to up, the linear actuator will extend and the backrest will rise and will fall when the back push button is pressed to down, the number of linear actuator on the back is 1 piece, if no button is pressed it will return to push button initialization and reading.

Unlike the Dental Chair Flowchart, the Dental Light flow on Figure 3 starts from the SHARP 2Y0A21 infrared sensor which will read objects at a distance of less than equal to 10 cm once, then the light will dim, then when there is another shadow object the light will light up brightly, when there is another shadow object, then the lamp will light up brighter and when there is a shadow object once again then the lamp will turn off, when there is no obstructing object then the reading will return to the previous reading.

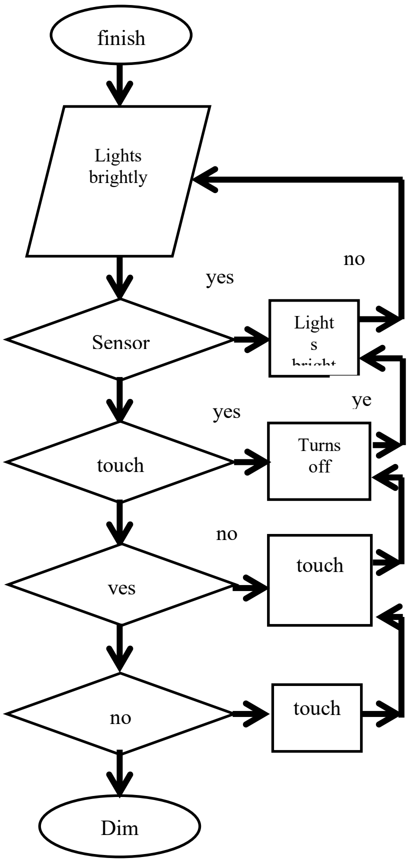

Figure 3. Dental Light Flowchart

2.3. Hardware Design

2.3.1. Microcontroller Circuit

The microcontroller circuit is used ATmega 328 IC. In this circuit, the Arduino bootloader is added to be programmed using the Arduino IDE [14]. The process of making the Arduino Uno module begins with the creation of a microcontroller that is added by the bootloader to the ATmega 328 IC. The next stage is to give the program and test its functionality. Figure 4 is the schematic of the circuit.

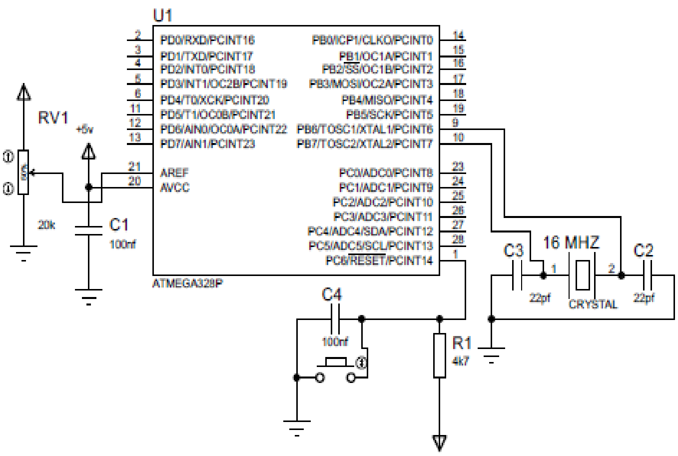

Figure 4. Microcontroller Circuit

2.3.2. Relay Driver Circuit

The relay driver circuit is used to execute commands from the microcontroller output to turn on the motor or load. The authors use relay drivers to run pneumatics, actuators and lamps. Figure 5 is the circuit of drivers used for dental light.

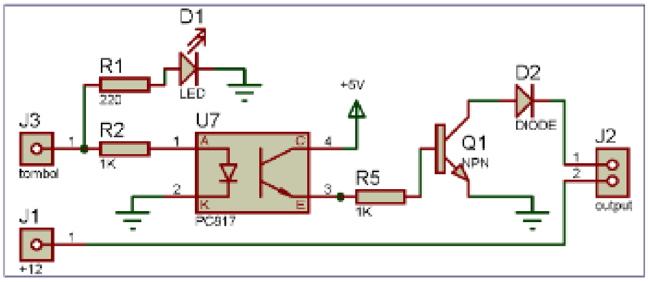

Figure 5. Driver Schematic Circuit for Dental Light

The dental light circuit uses an optocoupler as a non-contact switch, then goes to the NPN transistor, namely TIP120 as the output to the lamp. In this circuit the mode for changing the intensity is regulated through the coding of the microcontroller.

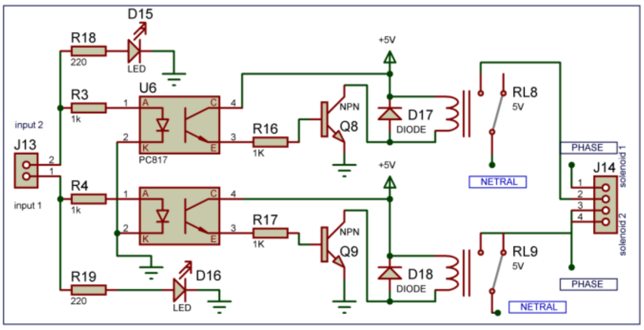

Figure 6. Pneumatic Driver Schematic Circuit

Figure 6 is the schematic of the pneumatic driver [12], the components used for the pneumatic driver are the PC817 optocoupler which is used as a non-contact switch and the NPN TIP120 transistor as a switch to activate the 5VDC relay, the output relay used is Normally Open (NO) and COM flows neutral from PLN and the phase is directly connected to the solenoid valve.

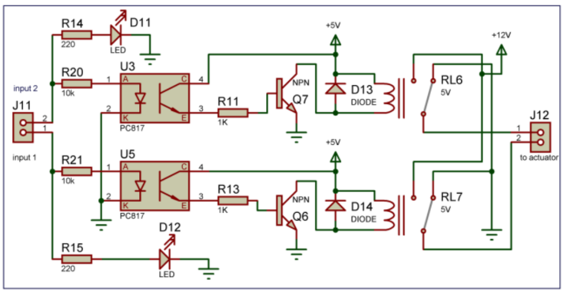

Figure 7. Actuator Driver Schematic

Schematic of Actuator driver can be seen on Figure 7. The components used in this circuit are the PC817 optocoupler as a non-contact switch and the NPN TIP120 transistor as a switch to the 5VDC relay. In the relays, the contacts will be controlled are Normally Open (NO) and Normally Close (NC), in this circuit the relay serves as an alternating voltage output [15].

2.3.3. Infrared Sensor Circuit

SHARP 2Y0A21 [13] sensor as a dental light switch with a distance of 0-10 cm, with switching modes from low, medium, high, off. The infrared sensor has 3 configurations: the first pin is connected to A0 pin, the second pin to ground, the third pin to VCC + 5V. The following is Figure 8 showing the SHARP 2Y0A21 Infrared sensor schematic.

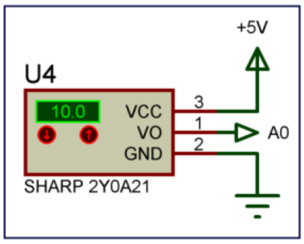

Figure 8. SHARP 2Y0A21 Infrared Sensor Schematic

3. RESULT AND DISCUSSION

3.1. Dental Chair Performance

3.1.1. The Testing of Controlling System

The testing of dental chair remote control was performed on actuators and pneumatics used to determine the movement of the up and down position as well as the lying down and upright position. The test was done 10 times on the up and down buttons for the pneumatic and 10 times on the up and down buttons for the actuator. The pneumatic up and down movement starts from the lowest position to the highest or maximum position, as well as the actuator, the test starts in the upright position until the lying down position. Table 1 is the result of testing the remote-control button carried out 10 times.

Table 1. Remote Control Buttons Testing Result

Tools	Condition	Accuracy
Pneumatic	Up	100%
	Down	100%
Actuator	Up	100%
	Down	100%

In Table 1, it can be seen that when the remote control button on the pneumatic is pressed ten times for the up button on the pneumatic to move up, and when pressed down, the pneumatic moves down, as well as for the actuator, when it is pressed ten times for the up button, the actuator moves upward and when the actuator is pressed down, the actuator moves down. The table shows the success of each button with an accuracy rate of 100% or as planned.

3.1.2. Load Testing

Load testing is performed on dental chairs using weight limits ranging from 20 kg to 120 kg in multiples of 20 kg. The test is conducted by pressing the up and down buttons on the chair or pneumatic 10 times for each weight limit. The test of the ability to lift loads is carried out on the pneumatic with the initial position at a height of 0 cm to a maximum position or 25 cm. The results of the unit capability test can be seen in Table 2.

Table 2. Result of Load Testing on Dental Chair

No	Weight Limitation (kg)	Actual Weight (kg)	Condition	Accuracy
1	20-40	32.3	Up	100%
			Down	100%
2	40-60	57.3	Up	100%
			Down	100%
3	60-80	69.2	Up	100%
			Down	100%
4	80-100	86.7	Up	100%
			Down	100%
5	100-120	118	Up	100%
			Down	100%

In Table 2, it can be seen that when the remote control for the chair or pneumatic is pressed on up button, the chair can be lifted, and can go down when the down button is pressed. The test was carried out 10 times on the five existing limits, starting from 20 kg to 120 kg with multiples of 20 kg. The results obtained can all be achieved or pneumatic can lift the load, and it is said to be successful with its accuracy level of 100%.

3.1.3. Load-Bearing Testing

The load-bearing testing was carried out on the dental chair to measure the strength of the pneumatic when holding the load for 5 minutes with a stopwatch gauge and a ruler to measure the drop of the pneumatic. The test was carried out 5 times with a chair height at a maximum condition or 25 cm and at a height of 15 cm. For loads used are weights for the weight limit of 20-40 kg and for other limitations used people whose weight was close to or within the weight limits that had been set. The results for the load-bearing testing on dental chair can be seen on Table 3.

Table 3. Results of Load-bearing Testing on Dental Chair

No	Weight Range	Actual Weight	Result	Lowering within 5 Minutes	
				Height 25 cm	Height 15 cm
1	20–40 Kg	32.3	Average	24.96	11.24
			Error (%)	0.16	25.06666667
2	40–60 Kg	57.3	Average	25	11.24
			Error (%)	0	25.06666667
3	60–80 Kg	69.2	Average	24.98	11.24
			Error (%)	0.08	25.06666667
4	80–100 Kg	86.7	Average	24.98	11.24
			Error (%)	0.08	25.06666667
5	100 – 120 Kg	118	Average	24.98	11.34
			Error (%)	0.08	24.4

In Table 3, the results of the load-bearing testing on the dental chair when holding loads with 5 weight limits within 5 minutes in the maximum seat height or 25 cm and at a height of 15 cm for 5 minutes at each limit. The average result for the maximum height or 25 cm can be said to be successful, because the error generated is not more than 1%, while for a height of 15 cm the error is ± 25% and there is a decrease in any limitations caused by the work system or specifications of the pneumatic that works with a piston that is raised when there is an input of air pressure, when at a height of 15 cm the piston is in the middle of the tube so that the air pressure is at the two poles, namely the top and bottom, which causes the pneumatic unable to hold the load optimally. In addition, a decrease can occur due to the widening of the seal or rubber on the pneumatic, causing air leak in the pneumatic [12], [15].

3.1.4. Chair Angle Tilt Testing

The test is carried out on a chair by measuring the tilt of the angle which can be achieved using an angular arc as a measuring tool. The results of the chair tilt testing can be seen in Table 4.

Table 4. Results of Angle Tilt Testing

No	Angle	Successful	Unsuccessful
1	110°		×
2	115°	✓	
3	120°	✓	

No	Angle	Successful	Unsuccessful
4	125°	✓	
5	130°	✓	
6	135°	✓	
7	140°	✓	
8	145°	✓	
9	150°		×
10	155°		×

In Table 4 we can see the results of testing the chair angle using an angular arc as a measuring tool carried out at an angle of 110° to 155° with a multiple of 5°. From the test results that have been carried out 10 times, it can be seen that chairs can only work at an angle of 115° to 145° which can be seen in Table 4 by providing a checklist or successful, while at an angle of 110°, 150° and 155° the chair cannot reach those angles by giving them cross (x) or unsuccessful.

3.1.5. Actuator Voltage Testing

Testing was carried out on the actuator which is on the back of the dental chair to find out how strong or capable the actuator is to withstand the load by calculating the voltage value when the actuator works to withstand varying loads, the voltage value is taken when the actuator rises and when the actuator drops from the initial position, upright to a lying position, data was taken 5 times for each weight limit, ranging from 20 to 120 kg. Voltage readings were made using a multimeter. The results of the actuator voltage testing can be seen in Table 5.

Table 5 Results of Actuator Voltage Testing

No.	Weight Range (kg)	Actual Weight (kg)	Condition	Average (Voltage)	Error
1	20–40	32.3	Up	11.6	3.33333
			Down	11.924	0.63333
2	40–60	57.3	Up	11.58	3.5
			Down	11.92	0.66667
3	60–80	69.2	Up	11.56	3.66667
			Down	11.92	0.66667
4	80–100	86.7	Up	11.548	3.76667
			Down	11.924	0.63333
5	100 – 120	118	Up	11.52	4
			Down	11.922	0.65

Table 5 is the result of the voltage reading on the linear actuator taken 5 times for each weight limit. In testing the actuator voltage, it can be seen that when the load used is heavier, the voltage on the actuator when it reverts tends to be stable at a voltage of ± 11.92, this result can be regarded as good because the specifications of the actuator are 12.00 volts and the error is ± 0.5%, so that the decrease is not that much. In the up position as the load applied becomes heavier, the actuator will work harder [15] until the resulting voltage is ± 11.55 volts and the error is ± 3.5%.

3.2. Result of Dental Light Performance Testing

3.2.1. Light Intensity Testing

The test of intensity or lux value in dental light was performed to find out the average light intensity in a lamp with three modes with a distance of 30 cm. Tests were performed 20 times in each mode using lux meter. The results of light intensity testing can be seen in Table 6.

Table 6. Results of Light Intensity Testing

No	Condition		
	Low	Medium	High
Average	2032.4	8435	20280

In Table 6 it can be seen the results of intensity testing on dental light using lux meter taken 20 times. The lamp used in the dental light is an LED with a voltage of 3.6 volts DC and a power of 10 watts. In the table it can deduced the average value in low mode is 2032.4, in medium mode the average value is 8435, and in high mode the average value is 20280. It can be seen from the testing results above the difference in light intensity which indicates the difference for low, medium, and high modes, with this mode the user can use the lamp according to its use so that patients and users feel comfortable when performing examination. For low and medium intensity, the result obtained is said to be low because it is still below the minimum light intensity of dental lamps which is 12000 lux, this is because the type of lamp used is still low power, which is of 10 watts.

3.2.1. Infrared Sensor Capability Testing

Testing was conducted to find out how accurate the SHARP 2Y0A21 infrared sensor was when reading the movement at a distance of 0-10 cm which was used as a switch to move the mode of dental light starting from low, medium, high and off. Testing was performed 10 times in each mode. The test was performed with an upright shadow position with the sensor position in accordance with the sensor specifications used. The results of the sensor capability test can be seen in Table 7.

Table 7. Results of Sensor Capability Testing

No	Condition	Accuracy (%)
1	Low	100%
2	Medium	100%
3	High	100%

In Table 7, it can be seen the accuracy of each mode performed by providing movement at a distance of 0-10 cm performed 10 times. In the table, it is shown that the accuracy in low mode of 100%, in medium mode of 100% and in high mode of 100%. These results show that the SHARP 2Y0A21 infrared sensor used as a switch can work well as planned [13].

4. CONCLUSION

In general, from the research, it can be concluded that dental unit prototype in form of electric dental chair and dental light can be used as a dental unit in general, that is, can move up and down for the chair, lying down and upright for the back by using a remote control, and dental light by using a sensor as a switch to switch the light intensity mode can work as planned. Meanwhile, Dental chair using pneumatic as an up and down actuator can work well with the result it can lift a load of more than 120 kg, with the load-bearing ability for 5 minutes with maximum height condition obtained error result of 1% and for half height obtained error of 25%. The back motor using an actuator can work well with an inclination angle of 115° to 145° with an average voltage output of 11.92 volts DC and in rising conditions an average voltage of 11.55 volts DC is produced. However, dental light can function according to its function with the average result in low mode of 2032.4, in medium mode the average produced is 8435, and in high mode the average value produced is 20280. The SHARP 2Y0A21 infrared sensor used as a switch to switch modes from low, medium, high and off can work well, judging from its 100% accuracy value.

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